Levitation: How Does It Work?

Levitating an object should be easy. All you need is a repulsive force strong enough to counteract Earth's gravity. So why not use an electric charge or a magnet to create the repulsive force? Scientists have been thinking about this idea for years. In fact, the first proposal to use magnetism to levitate vehicles was made in 1912, just one year after the discovery of superconductivity.

Superconductors can conduct electricity with no resistance at all. In normal conductors, moving electrons collide with atoms, a process that resists the flow of current and causes the conductor to heat up. Superconductors can carry large currents without heating up, which means that they can be used to create powerful electromagnets. Once the current is introduced into the superconducting wire, it can flow indefinitely, without dissipation, because there is no resistance. So, over time, the created magnetic field will not lose strength.

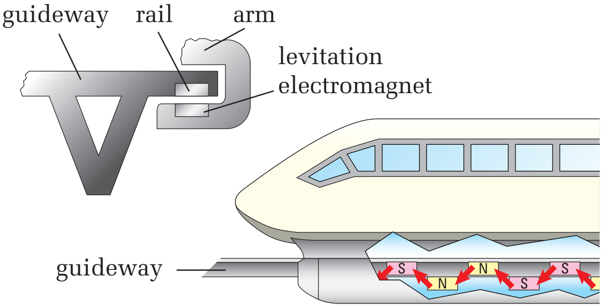
A Surprising Effect

What is the connection between superconductors and levitation? Superconductors have an additional surprising property when placed in a magnetic field. When a normal conductor is placed in a magnetic field, the magnetic field lines go right through the conductor — as if it was not there. When a superconductor is placed in a magnetic field, it expels the magnetic field from its interior and causes levitation. You can clearly see the levitation factor at work in a magnetically levitated (maglev) train — the train rides (or levitates) a few centimetres above the track (guideway).

Exciting Technology

Since the train rides above the guideway, what about propulsion? How does that happen? One design for a magnetically levitated train that is currently being built in Japan uses a push-pull system. Electromagnets are placed in the bottom of the train and along the track. The current is set so that the electromagnets along the track have opposite polarity to those on the train. It's possible, then, to have an unlike pole just ahead of each electromagnet on the train and a like pole just behind. The electromagnetic force pulls the unlike poles together and pushes the like poles apart.

After the train has moved forward enough to line up all of the electromagnets on the track and the train, the track electromagnets are briefly switched off. When they are switched on again, they have the opposite polarity, so that each electromagnet on the train is now pushed and pulled by those on the track. It's an intuitively basic design. The train's speed can be adjusted by timing the switches of the polarity of the track electromagnets. Slowing or braking the train is similarly accomplished.



Levitation electromagnets drawn up toward the rail in the guideway levitate Japan's magnetically levitated train.

Because the train rides a few centimetres above the track, there is no friction due to moving parts; this allows maglev trains to achieve much greater speeds than conventional trains. Test models in Japan and Germany have recorded speeds of 400 to 500 km/h. However, maglevs are expensive to build and operate. They have no wheels, so they cannot run on existing tracks and conventional trains cannot run on maglev tracks — so entirely new tracks must be built. Still, several countries are investigating how best to use this exciting new technology.

Levitation and Diamagnetic Materials

Levitation can also be achieved using certain types of materials, which are known as "diamagnetic" and are not superconductive. Diamagnetic materials are normally non-magnetic materials that become magnetized in a direction opposite to an applied magnetic field. Recently, physicists in Holland used a magnetic field of about 10 T to levitate a variety of seemingly non-magnetic materials, including a hazelnut, a strawberry, a drop of water, and a live frog. According to the researchers, the frog showed no ill effects from its adventure in levitation.

Frogs helped in levitation experiments and experienced no ill effects.

Then there's the other obvious question: Can people be levitated? In principle, the answer is yes, but in practice, the answer for now is no. Existing magnets are capable of levitating objects a few centimetres in diameter. Levitating a person would require an enormous electromagnet operating at 40 T, with about 1 GW of continuous power consumption. That's the same amount of power required to light 10 million 100 W light bulbs! Until more efficient ways can be found to make strong electromagnets, or people can be turned into frogs, people will be forced to walk with their feet on the ground.

Making Connections

1. Conduct a feasibility study for a maglev train to operate between two large cities.
2. Discuss the importance of space-based research and how diamagnetic levitation can be used to augment it.